Chapter 23
Development of Path Tracking Control Algorithm for a 4 DOF Spatial Manipulator Using PID Controller

Pradeep Reddy Bonikila
Indian Institute of Technology Bhubaneswar, India

Ravi Kumar Mandava
Indian Institute of Technology Bhubaneswar, India

Pandu Ranga Vundavilli
Indian Institute of Technology Bhubaneswar, India

ABSTRACT

The path tracking phenomenon of a robotic manipulator arm plays an important role, when the manipulators are used in continuous path industrial applications, such as welding, machining and painting etc. Nowadays, robotic manipulators are extensively used in performing the said tasks in industry. Therefore, it is essential for the manipulator end effector to track the path designed to perform the task in an effective way. In this chapter, an attempt is made to develop a feedback control method for a 4-DOF spatial manipulator to track a path with the help of a PID controller. In order to design the said controller, the kinematic and dynamic models of the robotic manipulator are derived. Further, the concept of inverse kinematics has been used to track different paths, namely a straight line and parabolic paths continuously. The effectiveness of the developed algorithm is tested on a four degree of freedom manipulator arm in simulations.

DOI: 10.4018/978-1-7998-1754-3.ch023

INTRODUCTION

From the past few decades, the usage of robotic manipulators in various applications such as in medicine, aerospace, automotive and high precision manufacturing of components and parts become more significant and therefore their study is important. These manipulators consist of links which are joined by joints mainly revolute and prismatic. Revolute joint allow rotation about that axis while prismatic joint allows relative translation about that axis. The linkage between the links make them to move relative to one another in order to achieve the required end effector position. In the present chapter, the path decided to perform a specific path has been traced by dividing it into small segments, and the corresponding joint angles made by these links is determined by using the concept of inverse kinematics.

The inverse kinematics problem can be solved by various methods such as, pseudo inverse, iterative and geometric approaches. Whitney (1969), introduced the pseudo inverse approach and showed that joint velocities obtained from the pseudo-inverse approach represent a particular path. In the literature, it was clearly demarcated that the trajectory planning is different from path planning and the later precedes the former. Path planning is defined by generating geometric path irrespective of the time law, while trajectory planning attaches a time law with path planning. In order to perform the job as required, the end effector of the robotic manipulator must follow predefined path between the initial and final (goal) points, which prevents any damage caused due to deviation from the path. Thus, it makes path planning an important task to be executed by the robotic manipulator. Several efforts were made by various researchers to develop an efficient path and design suitable control schemes for effective path planning.

Determination of inverse kinematics for a mechanism is a common technique in mechanical engineering, particularly in robotics community (Craig, 1986). However, analytical solutions for inverse kinematics for robotic manipulators are highly intricate and are difficult to apply for high-dimensional redundant manipulators (Chevallereau & Khalil, 1988). Instead, iterative and numerical techniques based on the calculation of the pseudo-inverse or the weighted pseudo-inverse of the Jacobian are introduced (Klein and C. Huang, 1983). Even though, the researchers propose many approaches, most of them lack in generality. Therefore in (Zhao & Badler, 1994), a new and feasible approach to solve the inverse kinematics had been proposed based on nonlinear programming methods. This nonlinear function was successfully applied to position the articulated manipulator and this helped in achieving satisfactory results. Deepak et al. (2000), implemented inverse kinematics algorithms using a combination of analytical and numerical methods to solve generalized inverse kinematics problems after including position, orientation and aiming constraints. It resulted in faster and reliable performance than the conventional methods of solving this problem. This methodology is applied to an anthropomorphic arm or leg. Dinesh et al. (1992), implemented an algorithm for the inverse kinematics of a 6R manipulator, which solve the inverse kinematics problem using multi-variable calculus that used symbol techniques, matrix computations and numerical methods.

Latombe et al. (1991), defined three important approaches such as: road-map, cell decomposition and potential field methods for sorting path planning problems. The authors explained the basics of path planning, like the Configuration space, free space and obstacles in C-space. In that study, they considered collision avoidance as a high level motion planning problem, which allowed the operation of manipulators in a hazardous and complex ambiance. Khatib (1985) and Volpe et al. (1990) developed artificial potential field method to represent the robots in C-space. With this method, the points in space was assumed to move under artificial potential created by the object configuration and the obstacles present in the C-space. Later on, (Faverjon et al., 1987) developed an alternative for artificial potential